RESEARCH DEPARTMENT

A STUDY OF ABSORPTION MEASUREMENTS BY THE REVERBERATION METHOD

Report No. B-074

(1962/47)

THE BRITISH BROADCASTING CORPORATION
ENGINEERING DIVISION

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SUMMARY

Comparison measurements of the absorption coefficient of a sample of mineral wool have been carried out in our reverberation rooms to assist the International Organisation for Standardisation to draw up proposals for the standardisation of such measurements.

Although a draft standard has now been drawn up on the basis of the international experiments it is felt that, at the moment, the results obtained by the method there proposed are not suitable for direct application in the design of broadcasting studios.

Further measurements to test methods of improving the consistency of results obtained in different rooms or to determine the fundamental properties of the material have therefore been undertaken.

1. INTRODUCTION

The absorption coefficients of materials required for the design of studios and similar enclosures are obtained by measurements of the reverberation time with and without the sample, in a highly reverberant room. The values are calculated by means of the formula developed by Norris and Eyring in which the reverberation time, T, is related to the volume, V, of the room, the total surface area of the room, S, and the average absorption coefficient of the surfaces, $\bar{\alpha}$, by the formula

$$T = 0{\cdot}049\ V/-S\ \log_e\ (1 - \bar{\alpha})$$

This formula assumes a diffuse sound field in the room and absorption of energy from the sound wave at each reflection from a boundary. A simplified formula due to Sabine is also used in many cases. This applies in a highly reverberant room where the wave motion is completely diffuse. The relationship is

$$T = 0{\cdot}049\ V/\bar{\alpha}S$$

Let $S = S_1 + S_2 + S_3 + \ldots\ldots S_n$ be the total surface area of the room. Then the mean absorption coefficient $\bar{\alpha}$ is defined from the equation

$$\bar{\alpha} = \sum_{r=1}^{n} \alpha_r S_r \Bigg/ \sum_{r=1}^{n} S_r = 1/S \sum_{r=1}^{n} \alpha_r S_r$$

where α_1, S_1, etc are the absorption coefficients and areas of each kind of boundary surface. These two formulae approximate to one another for low values of the absorption coefficient.

Results determined by such measurements depend on the way in which the sample is mounted, the area and location of the sample and the size and shape of the particular room, as well as upon the properties of the sample itself. For these reasons results relating to a particular material are subject to considerable variations between measurements carried out in different countries and in different reverberation rooms. Indeed in many cases a variation is found between measurements made by one authority at different times in the same reverberation room.

In order to reduce these variations, it was decided by the International Organisation for Standardisation (I.S.O.) that some degree of standardisation of procedure should be introduced. The German proposals for standardisation[1] required that reverberation rooms should be of a volume greater than 100 m^3 and that the sample, of area greater than 10 m^2, should be mounted either in one patch or divided and distributed on more than one surface. The reverberation room when empty was required to have reverberation times greater than 5 seconds below 500 c/s, 4 seconds at 1000 c/s, 3 seconds at 2000 c/s, 2 seconds at 4000 c/s and 1 second at 8000 c/s. It was also required that diffusion should be introduced in some manner, that a sound field should be set up by means of one or more loudspeakers in the reverberation room and that omni-directional microphones should be used to sample the decay of the sound field at at least three positions in the room. A level recorder was the preferred instrument for plotting the decays but other forms of equipment such as an oscilloscope and logarithmic amplifiers were not excluded. Records which show a monotonic curvature were to be excluded. This provision applies to the normal practice of displaying the curve on a logarithmic scale when an exponential decay is converted into a straight line.

It was felt by Dr. Cremer of Germany, a member of the I.S.O. Committee, that further experiments were required to clarify the position before standardisation was undertaken. The work described below was started at the request of the I.S.O. and extended to explore further possibilities.

2. INTERNATIONAL COMPARISON MEASUREMENTS FOR THE I.S.O.

2.1 First International Comparison 1958/59

With the co-operation of Grunzweig and Hartmann, the manufacturers, samples of a mineral wool called Sillan, of density 120 kg/m^3 and flow resistance 22 rayls/cm thickness, were sent to acoustic laboratories throughout the world. The mounting details supplied by Grunzweig and Hartmann indicated that the edges of the sample, which was 5 cm thick, should be surrounded by timber of dimensions 5 cm x 5 cm. The diagrams supplied suggested that sample areas 2 m x 1·5 m should be used and, since this coincided approximately with our normal procedure, the first set of measurements was carried out using the full sample of 12 m^2 sub-divided into four patches of the suggested dimensions. Measurements were carried out in the large reverberation room at Nightingale Square (N.L.) and the large reverberation room at Kingswood Warren (K.L.), using two different arrangements of the patches of

absorber in each room. (See Appendix for details of rooms.) For each arrangement measurements were made by four members of Acoustics Section; the absorption coefficients were subsequently averaged to give a mean value for each condition.

The results shown in Figs. 1 and 2 are the mean of the four determinations for each condition. It will be seen that a spread of 10% is found in the measured coefficients and that the difference between rooms is comparable with that for different dispositions in a particular room.

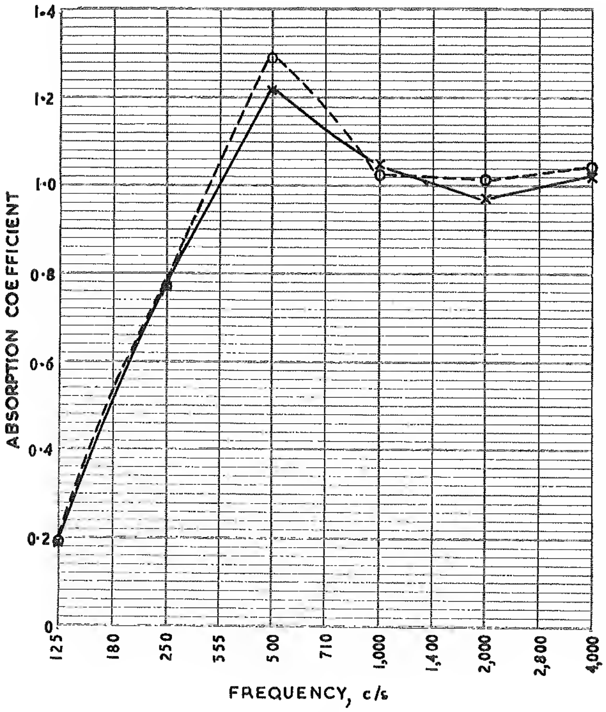

Fig. 1 - Absorption coefficients of Sillan sample (divided sample in N.L. Reverberation room) Effect of varying sample positions.

Results calculated by Sabine formula.

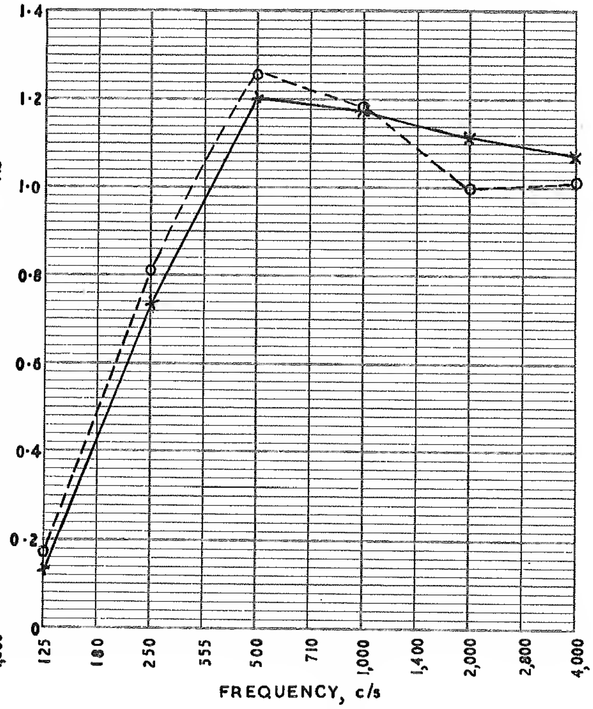

Fig. 2 - Absorption coefficients of Sillan sample (divided sample in K.L. Reverberation room) Effect of varying sample positions.

Results calculated by Sabine formula.

Each determination shows a peak absorption coefficient in the region of 1·20 to 1·30 at 500 c/s and a fall in the coefficient to about 1·00 above this frequency.

The means for generating a diffuse condition in the reverberation room were of interest to the organisers of the experiment. We reported to them that although in the Kingswood Warren reverberation rooms the vertical walls were non-parallel we did not consider this to provide adequate diffusion and our standard method was to divide the sample into four patches distributed on three surfaces of the room.

The conditions in the Nightingale Square reverberation room deviated further from the I.S.O. recommendations in the following respects: (i) the volume of the room was below the suggested figure of 100 m^3, (ii) the values of reverberation times for the empty room were shorter than the recommended values except at 125 c/s and (iii) microphones with figure-of-eight characteristics were used. In the Kingswood Warren reverberation room the only deviation from the I.S.O. recommendations was that the values of reverberation times for the empty room were shorter than the recommended values below 500 c/s.

2.2 Comments on First Comparison

The results supplied by the various measurement laboratories were analysed by Professor Kosten of the Netherlands and reported to the 3rd I.C.A. Congress in 1959.[2]

Kosten divided the reverberation rooms into five groups:

1. Those laboratories which followed the I.S.O. recommendations and used a single sample with adequate diffusion provided in the room by some means.

2. Rectangular rooms with a single sample but provided with insufficient diffusion.

3. Non-rectangular rooms with a single sample but no diffusion.

4. Rectangular rooms with divided samples.

5. Non-rectangular rooms with divided samples.

Fig. 3 is Kosten's graph of the absorption coefficient-frequency characteristic for each of these groups.

Those laboratories following the I.S.O. recommendations were in general in the middle of the range of results; they reached 100% absorption at about 1000 c/s and remained just above 100% up to 4000 c/s. Those laboratories classed as 2 and 3 above showed much lower absorption coefficients of the order of 75% at 1000 c/s and falling slightly above this frequency. Laboratories classed as 4 and 5 above showed results significantly greater than the I.S.O. group. A calculated value of the absorption coefficient for random incidence deduced from measurements at normal incidence in an impedance tube rose approximately to 90% at 1 kc/s and 93% at 2 kc/s and above. This will be referred to as α_{STAT}.

Taking into consideration the I.S.O. group only, Kosten found an apparent correlation between the mean absorption coefficient at and above 500 c/s ($\overline{\alpha}_{500\ldots}$) and a parameter related to sample area and room volume. This may be expressed as

$$\overline{\alpha}_{500\ldots} = K\ F/V^{2/3}$$

where K is a constant

F is the sample area

V is the room volume

2.3 Second Comparison 1959/60

In view of the wide divergence of results obtained during the first series of measurements, a request was made to the various participating laboratories that further measurements should be carried out, following more closely the recommendations laid down by the I.S.O.[3] The sample was to be tested as a single area on the floor of the reverberation room, diffusion being introduced by hardboard or plywood sheets a few millimetres thick and of area between 0·8 and 2 m^2. The sheets might be slightly curved. Sufficient diffusion is produced by hanging in a non-ordered manner a number of sheets such that the total area is approximately equal to that of the floor. (Fig. 4.) The projections of the area of the diffusers on the surfaces of the room should cover a similar percentage of each surface.

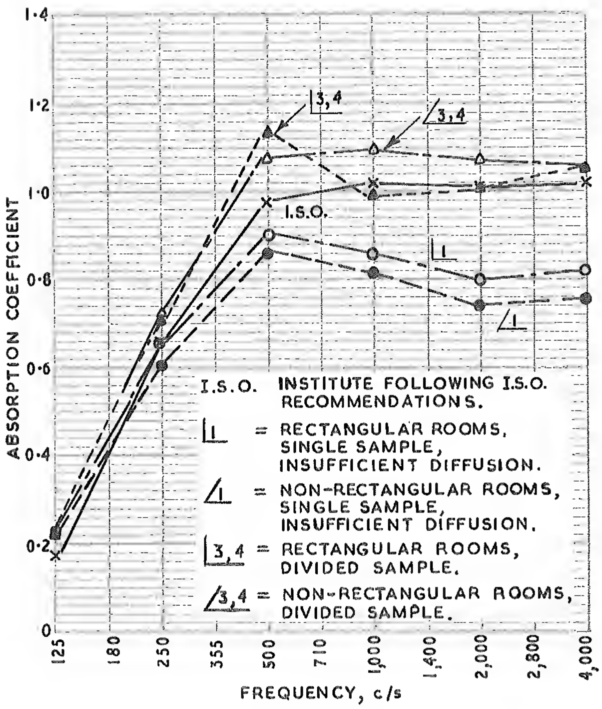

Fig. 3 - Absorption coefficients of Sillan sample. Mean values obtained by five groups of institutes using different methods of measurement.

It was requested, if time permitted, that measurements be carried out with sample areas of 4 m^2, 8 m^2 and 12 m^2. It was also considered of interest to vary the amount of diffusion from that which would be considered to be completely adequate to a condition of no diffusion. The suggested area of diffusing plates to provide adequate diffusion was 1·2 times the floor area of the reverberation room (in terms of the area of one side of the plates). An area of diffusing plate 0·8 times that of the floor area might possibly prove adequate while an area 0·4 times that of the floor area would not be expected to provide sufficient diffusion. In view of the large number of measurements involved in this series only one reverberation room was used, that at Nightingale Square, but for each condition measurements were carried out by three members of the section. Once again the mean of the absorption coefficients obtained by three observers was quoted as a final result.

The results obtained for the three sample areas are shown in Figs. 5, 6 and 7. The family of graphs in each figure shows the effect of varying the state of diffusion for that area of sample. The three conditions are identified by the actual area of diffusing plate used in each case, i.e. 34·5 m^2, 23 m^2 and 11·5 m^2.

Fig. 5 shows that, with the maximum sample area and adequate diffusion, results are obtained which agree with those reported by the other authorities which followed I.S.O. recommendations in the first series of measurements. The two higher degrees of diffusion produce results in close agreement with one another while the least area (11·5 m^2) of diffusing plate indicates only a slight fall in absorption coefficient at higher frequencies; this fall is of the order of the

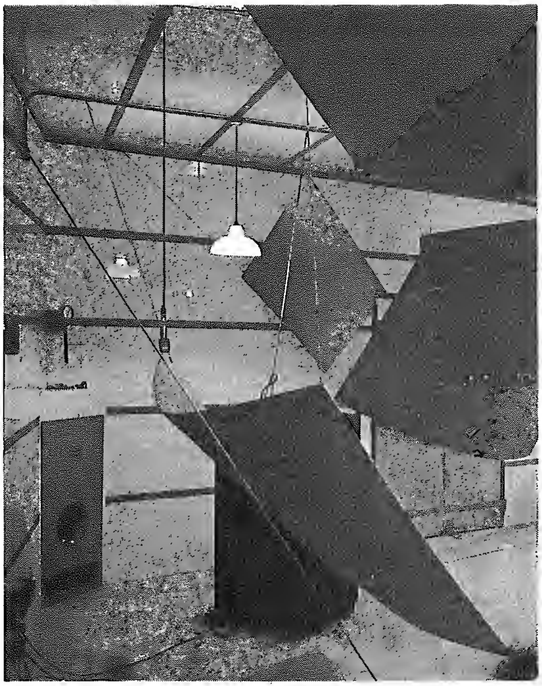

Fig. 4 - A reverberation room with added diffusion

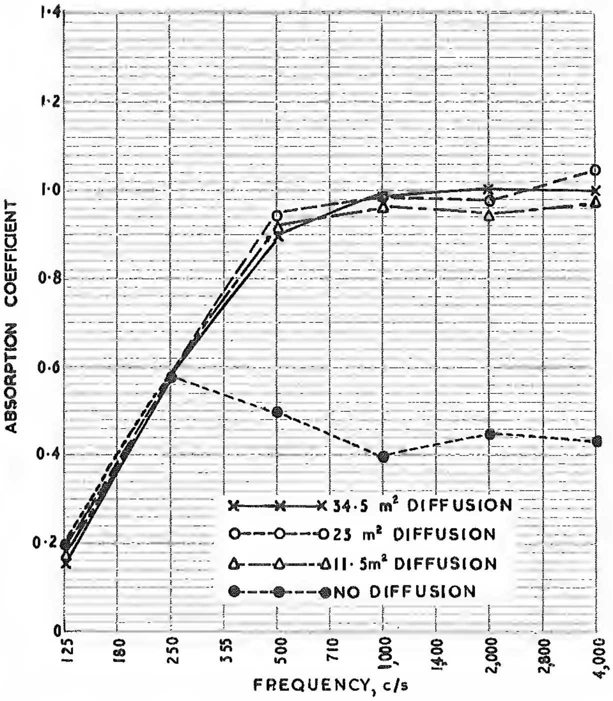

Fig. 5 - Absorption coefficients of Sillan sample. Effect of varying diffusion with 12 m² sample area.
Results calculated by Sabine formula

experimental error in the determinations. With no diffusion very low absorption coefficients result. The free edge per unit area of sample, a factor considered by Kosten in his analysis, is 1·17 m^{-1} in this case. The mean absorption coefficient at and above 500 c/s ($\overline{\alpha}_{500...}$) is 0·97 for the conditions of greatest diffusion.

The 8 m^2 sample (Fig. 6) shows higher absorption coefficients, due to greater diffraction effects; the free edge per unit area in this case is 1·5 m^{-1} and the value of $\overline{\alpha}_{500...}$ is 1·00 for the condition of greatest diffusion.

For the smallest area of sample the absorption shows a tendency to reach a peak value at 500 c/s and the results have a wider variation with change of diffusion (Fig. 7). The free edge per unit area of sample is 2·0 m^{-1} and the value of $\overline{\alpha}_{500...}$ is 1·10 for the condition of greatest diffusion.

As the sample area is reduced there is a greater spread of results with variation of diffusion and for a given degree of diffusion there is an increase in absorption. This effect is most noticeable in the absence of added diffusion and the greatest change occurs at 500 c/s.

2.4 Comments on Second Comparison

Following the completion of the second international comparison measurements, Professor Kosten carried out a further analysis of the results of both the first and second series of measurements.[4]

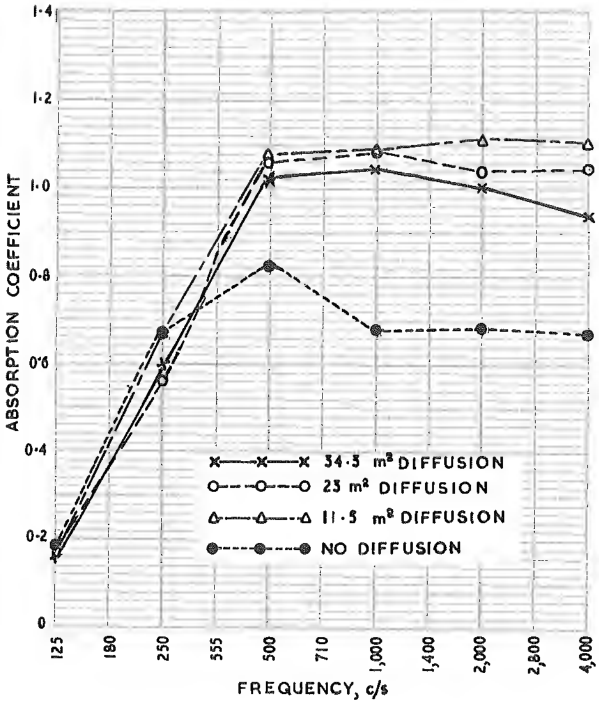

Fig. 6 - Absorption coefficients of Sillan sample. Effect of varying diffusion with 8 m^2 sample area.

Results calculated by Sabine formula.

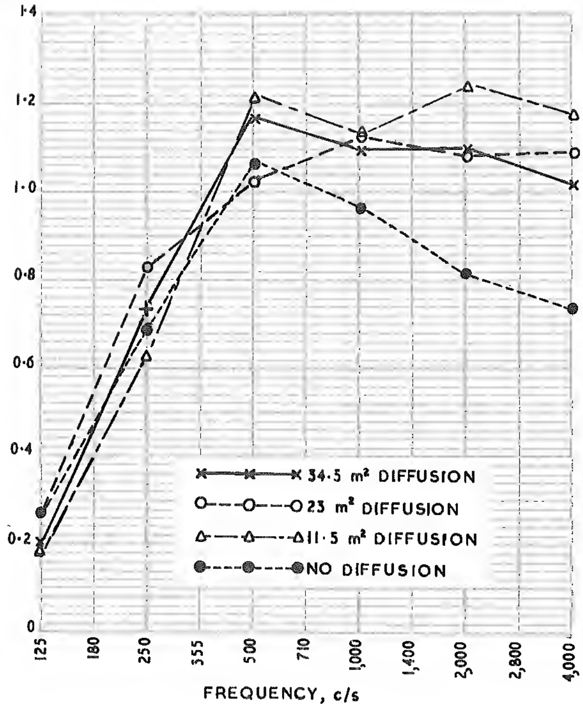

Fig. 7 - Absorption coefficients of Sillan sample. Effect of varying diffusion with 4 m^2 sample area.

Results calculated by Sabine formula.

A plot of the mean absorption coefficient obtained for the diffuse condition by the laboratories participating in these comparison measurements showed that as the sample area is reduced higher coefficients are obtained. A reduction of the sample area corresponds to an increase in the edge length per unit area, provided the ratio of the length to the breadth of the sample area is not greater than two.

It was also shown that reverberation rooms of volume greater than 150 m^3 (average volume 218 m^3) showed slightly higher values of absorption than those of volume less than 150 m^3 (average volume 108·5 m^3).

Since the absorption increased with increasing volume and decreasing sample area it seemed reasonable to examine the possibility of correlation between absorption and some factor such as $F/V^{2/3}$ or even F/S where

S = total surface of room

F and V as before

The results of the first comparison measurements supported a correlation with $F/V^{2/3}$ but when the larger number of results obtained in the second series was plotted the spread gave little hope of supporting any such relationship.

Kosten considers that a better explanation of the results is obtained by considering edge effect and diffusion. If a simple relationship such as $\alpha = \alpha_{\infty} + \beta E$ exists, where α is the measured coefficient corresponding to a certain value of E, the edge length per unit area of the sample, α_{∞} is the absorption coefficient for random incidence in the absence of any edge effect and β is a constant, a graph of α against E should prove to be a straight line. Since β may vary for different laboratories (say because of different ways of mounting the sample) any linear relationship should hold separately for each laboratory.

When the value of $\overline{\alpha}_{500\ldots}$, defined previously, is plotted against E it is seen that there is indeed a tendency for the results of each organisation to lie on a straight line and for the intercept at $E = 0$ to be about 88% which is the value of $\overline{\alpha}_{500\ldots}$ derived from the α_{STAT} curve. A similar graph for non-diffuse conditions shows a great spread of results, with the individual intercepts at $E = 0$ covering a wide range of values of $\overline{\alpha}_{500\ldots}$ below 80%. Of the non-diffuse rooms some gave results lying within the limits found for diffuse rooms; these proved to be measuring rooms provided with some inherent diffusion in the form of polycylindrical diffusers on the walls.

2.5 Discussion of International Experiments

As a result of his analysis of the international comparison measurements, Kosten reached certain conclusions which were supported by the I.S.O. Technical Committee 43 and included in the draft proposals for the measurement of absorption coefficients in reverberation rooms. These were that an area of 10–12 m^2 of sample was necessary to reduce edge effects to a reasonable value and that the room volume should be greater than 180 m^3 to enable diffuse conditions to be attained with such a large sample area.

The idea of dividing a sample to give an increase of diffusion was not accepted in view of the large increase in edge effect.

The international comparison measurements did not produce complete agreement on the proposed methods of standardisation. Some of the doubts and disagreements raised in this laboratory and elsewhere are mentioned briefly below.

The value of $\overline{\alpha}_{500\ldots}$ derived from impedance tube measurements is 88%. Because of the existing edge effect even with single sample methods a mean $\overline{\alpha}_{500\ldots}$ for such measurements is 101%. The mean for distributed sample measurements is about 110%. Both results include absorption due to diffraction effects and the results are therefore not immediately applicable in cases where the disposition of the treatment differs from that in the test conditions.

Kosten's conclusion that for small rooms with distributed samples the reduction of the efficiency of absorption due to poor diffusion is being used to offset an increase of absorption due to diffraction effects is not necessarily valid. The edge effect may have two components:

(a) The obvious increase of absorption due to diffraction at the edges.

(b) An increase of effectiveness of the area itself as a result of improved diffusion which is brought about by the distribution of the sample.

Until the relative size of the latter contribution is known it cannot be asserted that the edge effect is all of the nature of an error. It may be making up for the deficiencies of a small room in a perfectly legitimate manner. In fact, calculations of reverberation time requiring the greatest accuracy occur in broadcasting studios, many of which are small and have the absorption distributed in small patches. The measurements carried out by our method have proved adequate to provide, under controlled conditions, sufficient agreement between calculated and measured reverberation times.

The measurements so far described refer to only one material, and the behaviour with respect to sample size of other types of absorber such as resonant panels may be different.

Experiments following the standardisation proposals have shown that results are still subject to variations (of the order of 15–20% above 1 kc/s) when the positions of the sample or diffusers are altered without departing from the I.S.O. conditions.[5]

In view of the doubts expressed above and because further information on other methods of measurement was available, it was decided to continue the investigation in an attempt to obtain improved consistency of divided-sample measurements or a determination of the fundamental properties of the material.

3. CONSTANT PERCENTAGE SAMPLE AREA MEASUREMENTS

3.1 Method

Monsieur Pujolle of Radiodiffusion-Télévision Française[6] is of the opinion that the absorption coefficient measured for a sample is a function of the ratio, R, of the surface area of the sample to the total surface area of the room. If R is large the absorption coefficient is low. If the results obtained in the international comparison measurements for which the value of R is constant are examined there is no divergence between large rooms and small rooms. For the recommended room size of 200 m^3 and a sample size of 10 m^2, the value of R is 5% which gives rise to high values of absorption coefficient.

Treatment of 50 French studios with materials tested in rooms of volumes varying from 3 m^3 to 246 m^3 showed that if R is about 7% satisfactory designs are obtained. In these measurements the sample was divided into two patches.

An attempt was made using our reverberation rooms to verify the suggestions advanced by Monsieur Pujolle.

The following sample areas and divisions were used in these determinations:

(a) K.L. reverberation room. A sample of 12 m^2 area (8·2% of the surface area of the room) was divided into four patches mounted on three surfaces of the room.

(b) Small reverberation room, Kingswood Warren (K.S.). A sample of 8 m^2 area (9·3% of the surface area of the room) was divided into three patches mounted on three surfaces of the room.

(c) N.L. reverberation room. A sample of 10·5 m^2 area (8% of the surface area of the room) was divided into three patches.

(d) Small reverberation room, Nightingale Square (N.S.). A sample of 4·5 m^2 area (8·3% of the surface area of the room) was divided into three patches.

No added diffusion was used in these measurements. It should be noted, however, that at least one of Monsieur Pujolle's reverberation rooms has several hemicylindrical diffusers mounted on the wall.

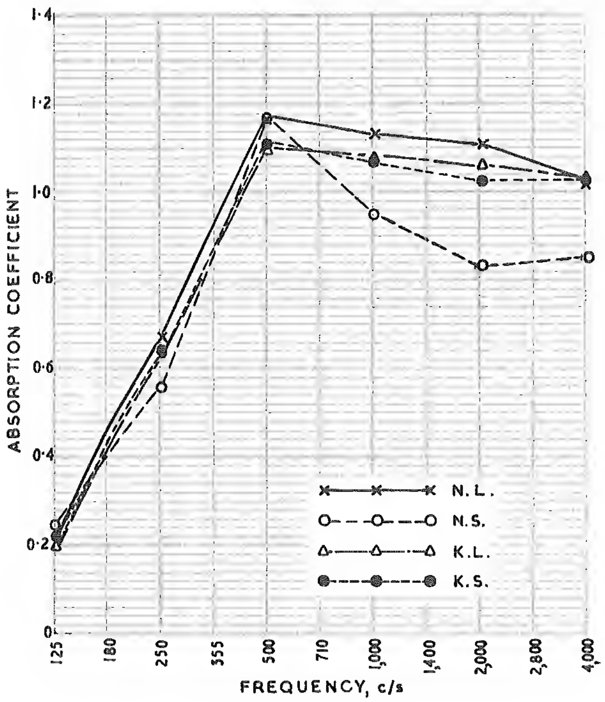

Fig. 8 - Absorption coefficients of Sillan sample. Measurements in four rooms using sample area which is a constant percentage of room surface.

Results calculated by Eyring formula.

3.2 Results

The results obtained for the four reverberation rooms are shown in Fig. 8, the absorption coefficient being calculated by Eyring's formula. There is extremely good agreement between the coefficients measured in three larger rooms but those for the smallest room fall above 500 c/s. This effect may be associated with the shape of the room, which is a cube.

It appears, therefore, that consistent measurements of the absorption coefficient of a mineral wool sample may be made, provided the sample area is kept as a constant percentage of the surface area of the room. In the absence of further information, rooms approximating to a cube should not be used for this form of measurement.

It is interesting to note that Monsieur Pujolle would consider our results to be too high, whereas we find that our results accord with accurate predictions of reverberation time. The peak at 500 c/s (which was not found in the R.T.F. determinations on Sillan) must be associated with the fact that we subdivide our sample into three or four patches while the R.T.F. only divide into two patches. The different individual areas involved therefore give rise to varying "edge effects".

4. "INFINITE AREA" MEASUREMENTS

4.1 Measurements with Edges of Sample Shielded

It has been suggested by Dr. Kuhl[7] that the disposition of a sample near to the side walls of a room, or the enclosure of the material by boards or frames,

causes a marked reduction in the edge effect. The absorption coefficient measured in this way should therefore approximate to the "infinite area" coefficient (α_{STAT}) i.e. that derived from impedance tube measurements at normal incidence, the effect of random incidence being calculated using the formula developed by Paris[8] for the porous type of absorber.

This proposal has been examined by experiments in the three larger reverberation rooms. In each case the sample was laid on the floor of the reverberation room in a corner so that two edges of the sample were against the walls of the room. The remaining two free edges were enclosed by concrete slabs 5 cm thick and 61 cm high, stood on edge.

Two measurements were carried out in each room with different amounts of diffusion provided by hardboard sheets as described previously. Kuhl recommends a smaller amount of diffusion than that specified in the second international comparison measurement since, in his opinion, too much diffusion increases the empty room absorption. He suggests tentatively that the diffusing surfaces should be 16% of the total room surface counting both sides of each plate.

In the experiments carried out the following sample areas and diffusion were used:

(a) K.L. reverberation room. A sample area of 12 m^2 was used with diffusion starting at 27%* of the room surface and increasing to 36% of the room surface.

(b) K.S. reverberation room. A sample area of 7·5 m^2 with diffusion starting at 27% and rising to 43% of the room surface.

(c) N.L. reverberation room. A sample area of 12 m^2 with diffusion starting at 16% and rising to 32% of the room surface.

For the two rooms at Kingswood Warren two observers carried out the measurements and at Nightingale Square three observers were employed. The results quoted are the mean of the absorption coefficients obtained in each case.

4.2 Results of Measurements with Shielded Edges

The results for the low diffusion condition are shown in Fig. 9; the low diffusion condition is shown since the amount of diffusion corresponds more closely to that proposed by Dr. Kuhl. An increase of diffusion was accompanied by an increase in the absorption at mid and high frequencies (500 c/s upwards) in the K.L. and K.S. rooms but by a decrease in the N.L. room. There is a considerable spread in the absorption coefficients obtained in these three rooms and all the results fall short of the α_{STAT} values.

It is suggested that this reduction of the absorption below the expected amount is due to a shadowing of the absorbers by the concrete slabs. This conclusion is suggested by a further measurement which was carried out in the Nightingale Square reverberation room. In this case a 12 m^2 sample was mounted in a corner of the

* Here and in what follows, the state of diffusion in the room is specified by the area of hardboard diffusing plates (both sides) expressed as a percentage of the room surface area.

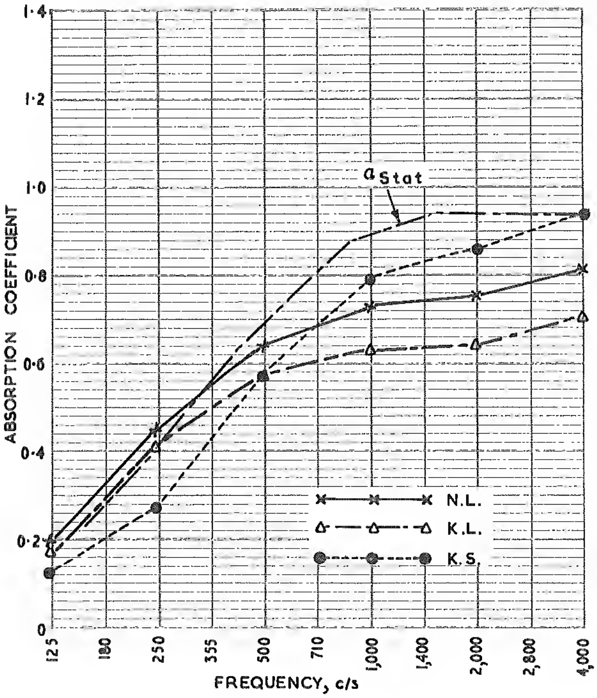

Fig. 9 - Absorption coefficients of Sillan sample with shielded edges. Measurements in three rooms with added diffusion. α_{STAT} is a curve derived from impedance tube measurements.

Results calculated by Eyring formula.

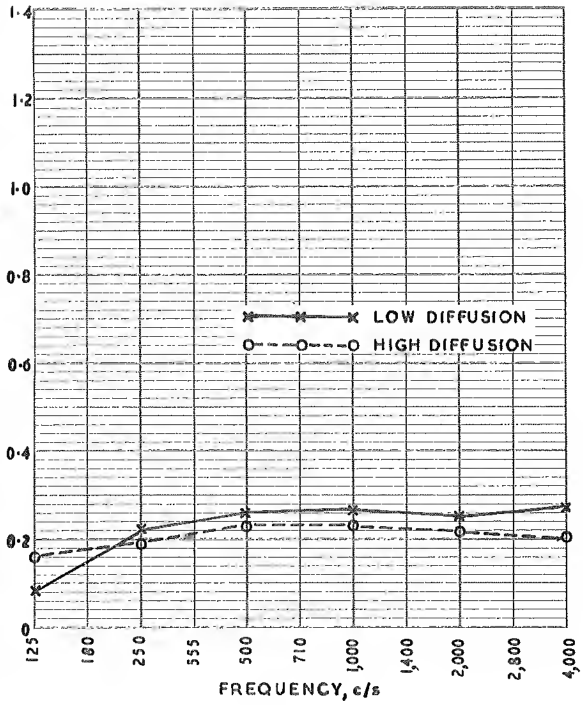

Fig. 10 - Absorption coefficients of Sillan sample. Sample mounted on three surfaces in corner with shielded edges.

Results calculated by Eyring formula.

room with 4 m^2 on each surface. The free edges were then enclosed by concrete slabs standing on edge as before and supported at right angles to the wall.

Measurements with two degrees of diffusion were carried out by three observers and the mean of the absorption coefficients so obtained are plotted in Fig. 10. Very low absorption coefficients are found which do not increase with increase of diffusion. In this case much more of the sample is surrounded by concrete slabs and hence a much greater degree of shadowing is obtained.

4.3 Measurements on Samples Totally Covering one Surface of the Room

If the test specimen covers the whole of one surface of the reverberation room and the measurements are made in a diffuse sound field, the edge effect is eliminated and results obtained which agree closely with those computed from tube measurements. Høy[9] describes measurements initiated by Professor Ingerslev in which three types of absorber, including a resonant absorber, were measured in rooms of volumes 96 m^3 and 0·88 m^3. Absorption coefficients measured in these two rooms of widely differing volumes agreed with one another. Agreement with computed values of α_{STAT} was found in these measurements.

Absorption coefficients were calculated by the Norris-Eyring formula and the diffuse field required for the application of this formula was obtained by hanging in the room diffusing elements (slightly curved varnished plates of hard fibreboard). The number of elements was decided on the basis of model experiments carried out by Høy and by earlier experiments by Meyer and Kuttruff. They used the criterion that the sound field was sufficiently diffuse when the measured absorption coefficient was the same as α_{STAT}. In the case of the large reverberation room the area of diffusing elements (counting both sides of the plate) was 47% and for the small reverberation room 45% of the surface area of the room.

The four reverberation rooms at our disposal were used to examine this method of eliminating edge effects. Sillan was used to cover one surface of the room and hardboard sheets hung as described previously to produce diffusion. The following areas of sample and amounts of diffusing surface expressed as percentages of the surface area of the room when measuring both sides of the plate were used:

(a) K.L. reverberation room. The area of sample was 22·6 m^2 and diffusion was varied from 27% to 36%.

(b) K.S. reverberation room. The area of sample was 11·0 m^2 and diffusion was varied from 28% to 43%.

(c) N.L. reverberation room. The area of sample was 12·3 m^2 and diffusion was varied in three steps of 16%, 29% and 40%.

(d) N.S. reverberation room. The area of sample was 9·5 m^2 and diffusion varied from 33% to 49%.

4.4 Results of Measurements with One Surface Covered

The results obtained in these measurements are shown in Fig. 11 compared with α_{STAT} as previously. These results are for the maximum degree of diffusion in each case and each determination is the mean of measurements by two or three people.

These results agree well with the value of α_{STAT} although the measurements in the largest room are rather too high. Increase of diffusion from 27% to 36% of the surface area produced no significant change in the measured absorption coefficient in this room, but it may be that there was still inadequate diffusion in view of the very large area of sample used.

It was noticed that in two of the rooms (K.S. and N.L.) there was a decrease of absorption coefficient on raising the degree of diffusion. This effect is shown in Fig. 12 for one of these rooms. Since this is contrary to normal expectation, it is intended to make further measurements to confirm or refute these results. It is considered possible that in non-diffuse conditions the distribution of the sample on one surface only would give rise to double decays which are rated subjectively shorter than the true average. On improving the degree of diffusion this effect will be reduced, resulting in the measurement of a longer reverberation time and so giving rise to a lower absorption coefficient.

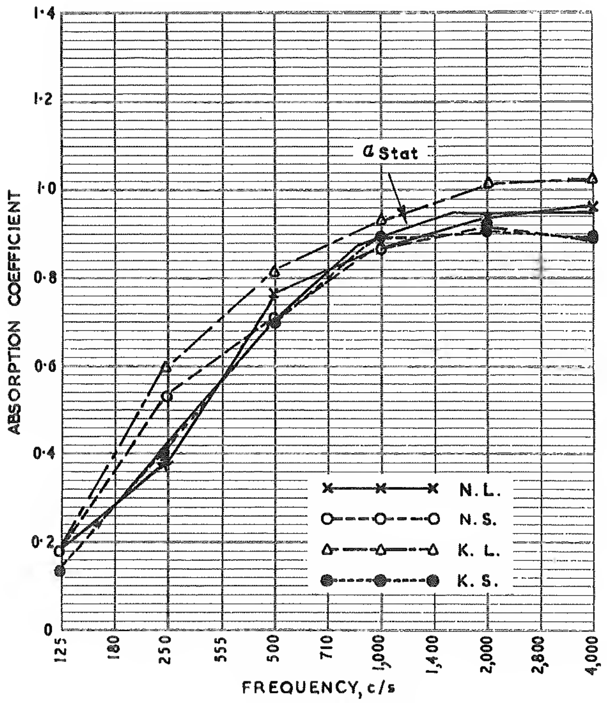

Fig. 11 - Absorption coefficients of Sillan sample. Measurements in four rooms with one surface covered.

Results calculated by Eyring formula.

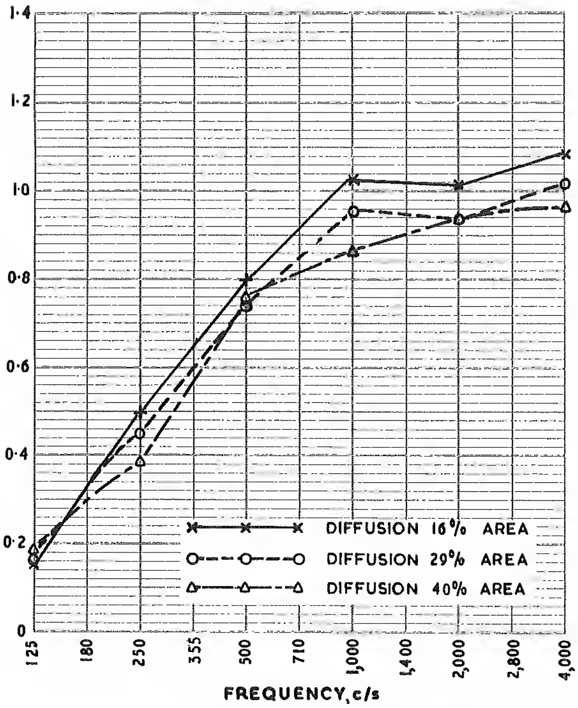

Fig. 12 - Absorption coefficients of Sillan sample covering one surface of room. Effect of varying diffusion.

Results calculated by Eyring formula.

5. CONCLUSIONS

In general, absorptive treatment is applied either in large unbroken areas with poor diffusion (offices, restaurants, etc) or in divided patches with some degree of diffusion (broadcasting studios, etc).

A determination of the absorption coefficient of a sample by the method proposed (and since adopted) as a standard by the I.S.O. gives a result containing some "edge effect", obtained in the presence of a high degree of diffusion. A determination of the infinite area absorption coefficient which has been shown to be possible with one surface entirely covered is again obtained in the presence of a high degree of diffusion. Neither of these results is directly applicable to design calculations until further information is available on the interaction between the various factors involved:

(1) Absorption coefficient of sample

(2) Physical dimensions of test sample

(3) State of diffusion in the measurement room.

Until further investigations can be carried out, measurements for use in studio design calculations will continue to be made by the divided sample technique that has been found to give satisfactory results under closely controlled conditions. The use of a constant percentage sample area has been shown to give consistent absorption coefficients in rooms of different volumes.

6. REFERENCES

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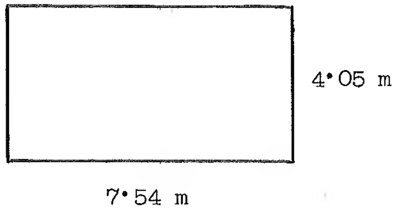
APPENDIX

Reverberation Room Characteristics

1. Designation N.L. (Nightingale Square Large Reverberation Room)

Plan and dimensions:



Height = 3·05 m

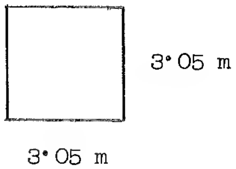
Volume = 91·8 m^3. Total Surface Area = 131 m^2. Floor Surface Area = 30 m^2

Empty room reverberation times:

freq (c/s)	125	250	500	1000	2000	4000
R.T. (secs)	7·0	4·4	3·8	3·1	2·4	1·6

2. Designation N.S. (Nightingale Square Small Reverberation Room)

Plan and dimensions:



Height = 3·05 m

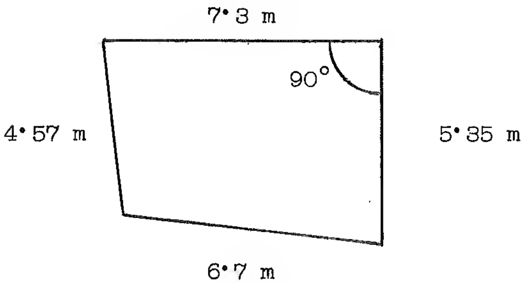
Volume = 28·4 m^3. Total Surface Area = 55·8 m^2. Floor Surface Area = 9·3 m^2

Empty room reverberation times:

freq (c/s)	125	250	500	1000	2000	4000
R.T. (secs)	3·2	2·6	1·6	1·7	1·6	1·5

3. Designation K.L. (Kingswood Warren Large Reverberation Room)

Plan and dimensions:



Height = 3·05 m

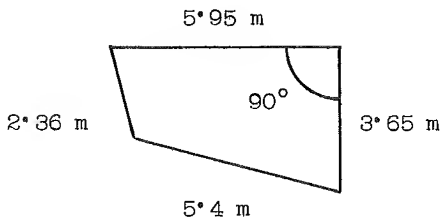
Volume = 108 m^3. Total Surface Area = 145 m^2. Floor Surface Area = 35·2 m^2.

Empty room reverberation times:

freq (c/s)	125	250	500	1000	2000	4000
R.T. (secs)	4·4	3·7	4·1	4·0	3·5	2·4

4. Designation K.S. (Kingswood Warren Small Reverberation Room)

Plan and dimensions:



Height = 3·05 m

Volume = 52 m^3. Total Surface Area = 86 m^2. Floor Surface Area = 17 m^2.

Empty room reverberation times:

freq (c/s)	125	250	500	1000	2000	4000
R.T. (secs)	4·0	3·1	3·0	3·3	2·9	2·4

ALG

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